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Niche partitioning by soil mites in a recent hardwood plantation in Southern Québec, Canada

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With 2 figures

Synopsis: *Original scientific paper*

Using principal component analysis, the synecological study of soil mites in a recent hardwood plantation on clay soil in the area of Mirabel, Quebec highlighted the major influence of certain environmental parameters in the spatial distribution of organisms.

The horizontal clumped distribution of mites is determined by the importance of the herbaceous layer, the relative humidity, the temperature, the potassium and sodium contents and by the quantity of organic matter.

Nothrus truncatus Banks and *Cultroribula divergens* JACOT along with the genera *Scheloribates*, *Galumna*, *Pergalumna* and *Pseudoparasitus*, preferred the coolest, most humid sites which were also the highest in potassium and the lowest in sodium. *Tectocepheus velatus* (MICHAEL), *Opiella nova* (OUDEMANS) and *Zygoribatula cf. fusca* EWING were found in soil relatively low in organic matter while *Eremulus cf. cingulatus* JACOT, *Xylobates capucinus* (BERLESE) and *Rhizoglyphus* sp. were found in high organic matter areas.

Keywords: Acari, Oribatei, synecological study, hardwood plantation, distribution, niche partitioning, South Québec, Canada.

1. Introduction

Among soil arthropods, mites are often the best represented group in terms of numbers (TOUSIGNANT *et al.*, 1988), richness and diversity (ANDERSON, 1975; WALLWORK, 1970). They play an important role in decomposing organic matter (DRIFT, 1970), in recycling and in increasing nutrients availability (LUXTON, 1982; SEASTEDT, 1984) and stability (BERG & PAWLUK, 1984; HOLT, 1981).

The spatial distribution of mite populations generally depends upon their reaction to biotic and abiotic environmental conditions (BONNET *et al.*, 1975); SCHENKER, 1984). Many authors have shown the often indirect and variable influence of factors such as porosity (LOOTS & RYKE, 1967), soil structure (ABBOTT *et al.*, 1979), humidity (FORD, 1938; VANNIER, 1970; WEIS-FOGH, 1948), temperature (MITCHELL, 1979; REEVES, 1973), concentration of nutrients and percentage of organic matter (HOLT, 1981; SCHENKER, 1984; USHER, 1976).

The strong lateral variability of these ecological factors, creates many different microhabitats (ARP & KRAUSE, 1984; USHER, 1976) and leads us to expect that the distribution of organisms would be clumped. Thus, they are found in the most stable microhabitats (HAARLOV, 1960), where conditions are most favourable (AOKI, 1967; HAMMER, 1972; USHER *et al.*, 1982).

Until now, most analyses studying the influence of environmental factors on soil fauna used correlations (USHER *et al.*, 1982); very few authors used multivariate analysis to illustrate overall relationships (BONNET *et al.*, 1975; PAN, 1980). In this study, we used

principal component analysis to show how troglophilic mites partition the multidimensional space of their resources and how the environment affects their spatial distribution.

2. Experimental site

The study was carried out in 1984 and 1985 in an experimental plantation on a fallow field in the south concession of Belle-Rivière, municipality of Mirabel, Québec (74° 04' N – 45° 37' W). This region is characterized by a long growing season. At Mirabel, during the years 1984 and 1985, the average annual temperature was 4.8 °C and the total average annual precipitation was 953 mm (Environment Canada, pers. comm.). The terrain is flat, free of surface rocks and poorly drained. The soil profile is made up of a deep layer of grey clay. The herbaceous layer is dominated by couch grass *Agropyron repens* (L.), timothy (*Phleum pratense* L.), wold parsnip (*Pastinaca sativa* L.), goldenrod (*Solidago spp.*) and vetch (*Vicia cracca* L.).

Two hundred 5 year-old white ash (*Fraxinus americana* L.) were planted on 0.34 ha of this site in October 1983. Half this area was tilled before planting and harrowed monthly during the following years (1984: June 20, July 20, August 20; 1985: June 11, July 10, August 11). The second half was never worked.

3. Method

Mesofauna sampling was done from May 21 to 27 1985. Fifteen soil samples were collected randomly from each of the two sectors: the first with a more or less bare surface due to cultivation and the second completely covered with herbaceous vegetation.

Sampling consisted of volumetric samples (5 cm × 5 cm × 10 cm) of the upper soil layer (0 – 10 cm), this zone being recognized as the richest in mesofauna (Berg & Pawluk, 1984; Petersen & Luxton, 1982; Wallwork, 1970). Mesofauna extraction involved a modification of the method proposed by Salt & Hollick (1944). The procedure has five steps: the addition of a dispersing agent and freezing (–5 °C for 48 hours): wet sieving (1 mm, 0.5 mm, 0.15 mm), double flotation (sucrose 1 : 1.5), double filtration and exhaustive counting of organisms. This method, which allows for the extraction of a great variety of organisms, is the most widely used of the mechanical methods (Edwards & Fletcher, 1971; Murphy, 1962). It is similar to Macfadyen's (1961) gradient method but has certain advantages in terms of the efficiency of organism extraction in clay soils (Murphy, 1962). As well, the procedure depends neither on the behaviour of the organisms, nor on the substrate conditions and the sample may be kept several days before extraction (Southwood, 1975).

Soil analysis for each sampling unit used a sample (0 – 10 cm) contiguous with that from which the pedofauna was extracted. Ca, K, Mg, and Na contents were determined using atomic-absorption spectrophotometry after extraction with ammonium acetate (1 N); nitrate concentrations were evaluated using continuous flux spectrophotometry after extraction with KCl. The *p*H was measured using a glass electrode *p*H meter in a 1 : 1 solution soil/water. Soil humidity was determined using the difference in weight before and after drying. The organic matter content was measured by loss on ignition (500 °C for 16 hours). Soil temperature at a depth of 5 cm, as well as the percent herbaceous cover, were noted when sampling.

The aggregation index for each of the mites populations was calculated using the relative variance index $\lambda = S^2/x$ and tested using χ^2 with $n - 1$ degrees of freedom: $\chi^2 = (n - 1)\, S^2/x$ (Cancela Da Fonseca & Stamou, 1982) where null hypothesis corresponded to a random distribution.

Principal component analysis (Legendre & Legendre, 1984) was used to search for biological associations based upon abiotic habitat characteristics. Based on the correlation matrix of species abundance rather than on the variance, the analysis shows the variance of population structure by according a priori the same importance to rare and sparse species as to very abundant and very variable ones (Scherrer, 1984). In order to determine which factors were involved in the species' distribution, Kendall's correlation coefficients were calculated between the coordinates for each of the stations on the first three axes of the principal components and for the ten abiotic variables.

4. Results

The dispersion index calculated for each taxon studied shows that the majority of them are clumped (table 1). Mites whose total abundance was less than three as well as

Table 1. Aggregation index (λ) of soil mites in a recent hardwood plantation in the south concession of Belle-Rivière, Mirabel, Québec.

Taxa		λ	p
Astigmata			
Acaridae	*Rhizoglyphus sp.*	2.70	***
Cryptostigmata			
Astegistidae	*Cultroribula divergens* JACOT, 1939	2.32	***
Carabodidae	*Carabodes cf. brevis* BANKS, 1896	1.08	
Cepheidae	*Ommatocepheus clavatus* WOOLEY & HIGGINS, 1964	1.08	
Eniochthoniidae	*Eniochthonius minutissimus* (BERLESE, 1903)	1.96	***
Eremulidae	*Eremulus cf. cingulatus* JACOT, 1937	0.96	
Galumnidae	*Acrogalumna* or *Galumna sp.*	9.38	***
	Pergalumna sp.	22.31	***
Haplozetidae	*Xylobates capucinus* (BERLESE 1908)	3.28	***
Mochlozetidae	*Podoribates sp.*	2.77	***
Mycobatidae	*Punctoribates sp.*	1.16	
Nothridae	*Nothrus truncatus* BANKS, 1895	4.81	***
Oppiidae	*Oppiella nova* (OUDEMANS, 1902)	6.91	***
Oribatulidae	*Dometorina sp.*	1.08	
	Zygoribatula cf. fusca (EWING, 1913)	6.18	***
Phenopelopidae	*Eupelops sp.*	2.13	***
Scheloribatidae	*Scheloribates sp.*	17.36	***
Tectocepheidae	*Tectocepheus velatus* (MICHAEL, 1880)	23.5	***
Thyrisomidae	*Banksinoma spinifera* (HAMMER, 1952)	1.56	*
Total		**49,82**	***
Mesostigmata			
Ascidae	*Cheiroseius borealis* (BERLESE)	0.89	
Eviphididae	*Eviphis sp.*	1.08	
Laelapidae	*Hypoaspis sp.*	1.77	**
	Pseudoparasitus sp.	0.96	
Ologamasidae	*Gamasellus vibrissatus* (EMBERSON)	1.24	
Parasitidae	*Pergamasus sp.*	2.82	***
Phytoseiidae	*Amblyseius sp.*	0.96	
Total		**3.42**	
Prostigmata			
Bdellidae	*Bdellodes (? Thoribdella) sp.*	1.08	
Scutacaridae	*Scutacarus sp.*	1.08	
Stigmaeidae	*Eustigmaeus sp.*	1.08	
	Stigmaeus sp. cf. sphagneti (HULL)	1.08	
Tetranychidae	*Bryobia sp.*	2.50	***
Trombidiidae	*Microtrombidium sp.*	1.09	
Total		**1.88**	***
Total		**49.81**	***

$P = \chi^2$ significance level on aggregation index (λ): * $p < 0.05$, ** $p < 0.01$, *** $p < 0.01$.

Punctoribates sp. m., *Gamasellus vibrissatus* (EMBERSON) and *Microtrombidium sp.* show a lower aggregation index.

From 32 mite taxa identified, 22 were retained for factor analysis. The others, considered rare (observed fewer than three times) were eliminated from the analysis to allow a better separation of the principal components (LEGENDRE & LEGENDRE, 1984).

Figure 1 and table 2 illustrate the contributions of variables to the first three axes as well as the projection of the correlation angles between the variables in this plane. The

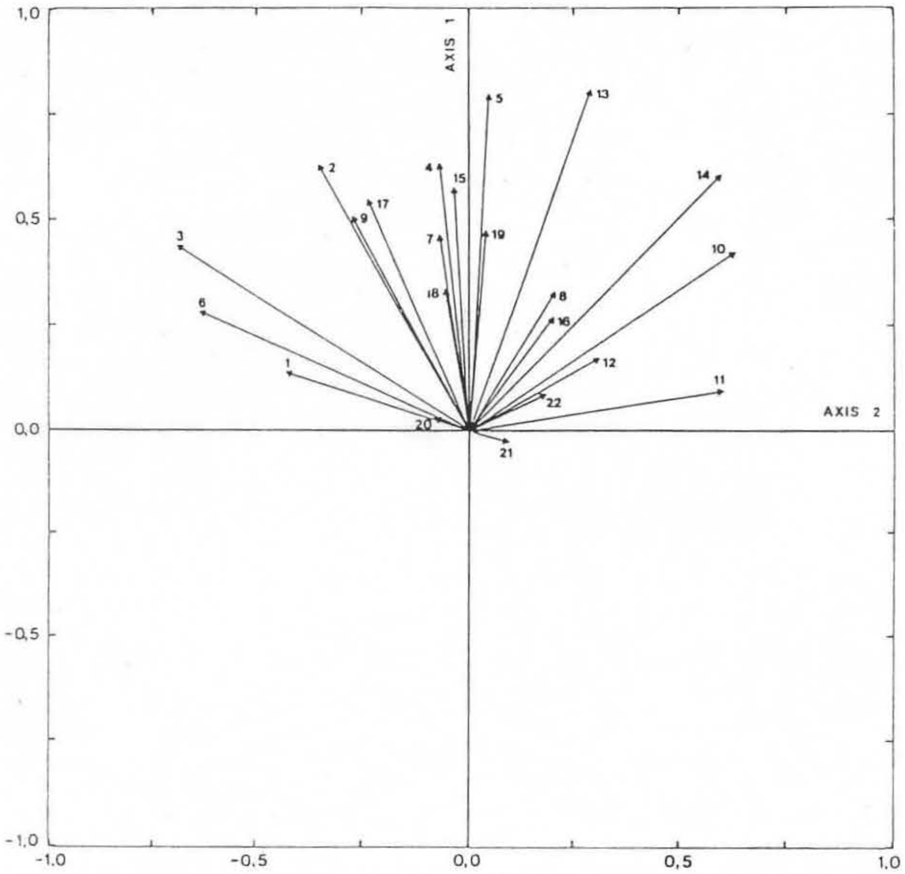

Fig. 1. Position of soil mite species on the first two axes of the principal components analysis. 1 – *Rhizoglyphus sp*; 2 – *C. divergens*; 3 – *E. cf. cingulatus*; 4 – *Acrogalumna sp.*; 5 – *Pergalumna sp.*; 6 – *X. capucinus*; 7 – *Podoribates sp.*; 8 – *Punctoribates sp.*; 9 – *N. truncatus*; 10 – *O. nova*; 11 – *Z. cf. fusca*; 12 – *Eupelops sp.*; 13 – *Scheloribates sp.*; 14 – *T. velatus*; 15 – *B. spinifera*; 16 – *Hypoaspis sp.*; 17 – *Pseudoparasitus sp.*; 18 – *G. vibrissatus*; 19 – *Pergamasus sp.*; 20 – *Amblyseius sp.*; 21 – *Bryobia sp.*; 22 – *Microtrombidium sp.*

first component explains 20.6% of the total variance, while the second and third account for 12.5% and 11.8% respectively. All variable vectors which contribute significantly to the formation of the reduced system are located in the positive part of axis 1.

The first group of mites strongly associated with this axis is composed of the Oribatids *Nothrus truncatus* BANKS, *Cultroribula divergens* JACOT, *Scheloribates sp.*, *Acrogalumna sp.*,

Table 2. Kendall's correlation coefficients between abiotic variables and the coordinates for each of the stations on the first three axes of the principal composants.

	humidity	temperature	herbaceous layer	% organic matter	K	Na
Axis 1	0.379**	−0.394**	0.364**	0.191	0.304*	−0.325*
Axis 2	0.223	0.127	−0.244	−0.310*	−0.219	−0.153
Axis 3	0.071	−0.075	−0.026	0.029	0.073	0.023

* $p < 0.05$
** $p < 0.01$

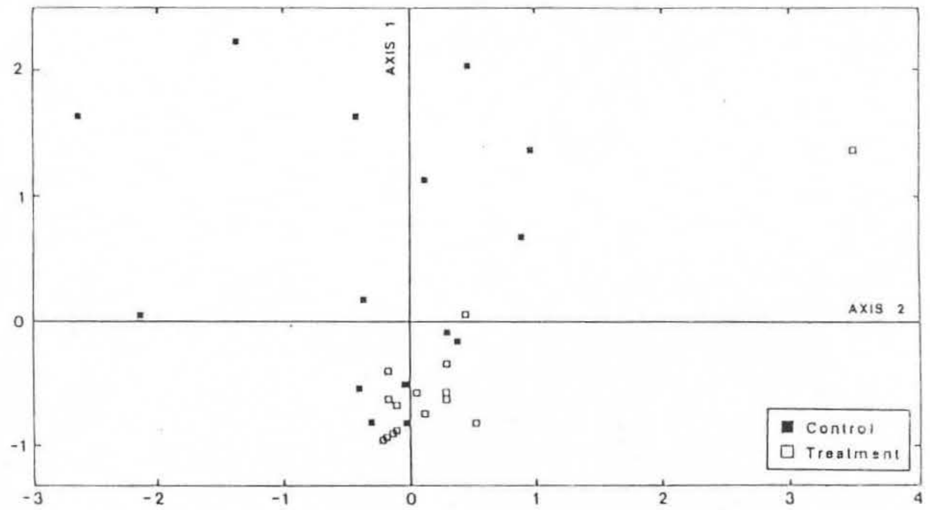

Fig. 2. Position of sampling units on the first two axes of the principal components analysis.

Pergalumna sp., and of the Mesostigmatid *Pseudoparasitus sp.* To a lesser extent, the Oribatid *Banksinoma spinifera* (HAMMER) and the Mesostigmatid *Gamasellus vibrissatus* (EMBERSON) and *Pergamasus sp.* are also associated with it. Finally, the abundance of *Tectocepheu velatus* (MICHAEL) is correlated positively and equally with the first two axes.

The second group of mites, having a strong negative correlation with axis 2, includes the species *Eremulus cf. cingulatus* JACOT and *Xylobates capucinus* (BERLESE) and, to a lesser extent *Rhizoglyphus sp.*

The third group is made up of species whose vectors have a strongly positive correlation with axis 2 and a moderately negative correlation with axis 3. These are the Oribatid *Oppiella nova* (OUDEMANS) and *Zygoribatula cf. fusca* (EWING).

Podoribates sp., *Punctoribates sp.* and *Microtrombidium sp.* make up the last group and have a strong positive association with the third component.

It must be noted that the variables whose vector limit approaches the origin of the axes cannot be explained by the components under consideration, that is, they can be distinguished only in relation to other components. This is the case with the genera *Hypoaspis*, *Amblyseius*, *Bryobia* and *Eupelops*.

In the plane defined by the first two axes (Fig. 2) the first principal component separates the stations into two distinct groups. The majority of these points illustrating stations in the cultivated sector are in the negative section of the first component, while the stations belonging to the uncultivated sector are in the positive section.

The environmental parameters evaluated at each station were correlated with the principal component scores (table 2). Percent coverage of the herbaceous layer, percent humidity and potassium content were positively correlated with the first component, while temperature and sodium content were negatively correlated. The second axis is associated negatively with the amount of organic matter and the third axis is not significantly correlated with any other abiotic factor.

Nitrate, magnesium and calcium concentrations and pH were not significantly correlated with any of the three first principal components.

5. Discussion

Dispersion is an intrinsic characteristic of a population and one of the main features of the structure of an animal community (REISE & WEIDEMAN, 1975). A random distribution

which presupposes a lack of response to and a strong tolerance for environmental factors is rarely seen in living organisms (DEBAUCHE, 1958). The vast majority have a clumped spatial distribution. Soil organisms are no exception (BUTCHER *et al.*, 1971; MITCHELL, 1978; SCHENKER, 1984; USHER *et al.*, 1982). Most of the taxa inventoried here follow this pattern (table 1).

The spatial distribution of organisms is affected by a host of environmental factors, all more or less interrelated (DHILLON & GIBSON, 1962). Soil complexity makes it difficult to consider every variable which might influence the size or distribution of microarthropods (CHOUDHURI & ROY, 1967).

Among the abiotic factors measured, relative humidity, temperature, potassium and sodium content and the amount of organic matter appear to be the most important in the distribution of soil mites. These organisms were found mainly in sampling stations with surfaces completely covered with vegetation. This herbaceous cover helps stabilize soil and temperature conditions (TOUSIGNANT *et al.*, 1988) and keeps organic matter in the soil. This last factor constitutes not only an important food source but also affects soil structure and thus the availability of space for edaphic organisms (BANERJEE, 1984; HAARLOV, 1960; SCOTT *et al.*, 1983).

The lack of influence of *p*H, and of nitrate, calcium and magnesium concentrations on the distribution of these mites is explained in part of the low variations in the values recorded for these factors. It is also plausible that these factors are not limiting at the measured concentrations. According to KEVAN (1962), mites would be influenced only by extreme *p*H values.

Certain groups of mites could be recognized and related to environmental components studied. *N. truncatus* and *C. divergens*, along with the genera *Scheloribates*, *Galumna*, *Pergalumna* and *Pseudoparasitus* were found in the coolest and the most humid sectors, where potassium concentration was the highest and sodium the lowest (fig. 1, table 2). *B. spinifera*, *G. vibrissatus*, *Pergamasus sp.* and *T. velatus* appear less dependent upon these factors. The latter, whose ecological role is recognized within mite communities (SCHENKER, 1984b), is considered to be highly tolerant of fluctuations in humidity, temperature and *p*H (SCHENKER, 1984; USHER, 1975; WALLWORK *et al.*, 1985); it is known as an ubiquist species (BONNETT *et al.*, 1975).

With the exception of *T. velatus*, the differences in the amount of organic matter measured did not influence the distribution of the organisms mentioned above. *T. velatus*;was found in stations relatively poor in organic matter in association with *O. nova* and;*Z. cf. fusca*. On the other hand, *E. cingulatus*, *X. capucinus* and *Rhizoglyphus sp.* were in the richest sectors.

The genera *Podoribates*, *Punctoribates*, *Eupelops*, *Hypoaspis*, *Amblyseius*, *Bryobia* and *Microtrombidium* could not be segregated by any factors and could not be put into an association. According to WALLWORK (1967) certain Prostigmata of the family Trombidiidae (*Microtrombidium*) are not true soil organisms. For instance *Bryobia* lives mainly on vegetation (KÜHNELT, 1961), and several species of the family Phytoseiidae, genus *Amblyseius*, are airborne species preying upon phytophagous mites (KRANTZ, 1970).

The clumped horizontal distribution of soil mites is caused by various environmental factors. The herbaceous cover, relative humidity, temperature, potassium, sodium and organic matter content largely influence the composition and abundance of these organisms.

6. Résumé

L'étude de la synécologie des acariens édaphiques d'une plantation récente de feuillus sur argile grise de la région de Mirabel, Québec, nous a permis, par le biais d'une analyse en composantes principales, de mettre en évidence l'influence majeure de certains paramètres environnementaux sur la distribution spatiale des organismes.

L'importance de la strate herbacée, de l'humidité relative, de la température, de la teneur en potassium et en sodium, et de la quantité de matière organique, détermine la répartition horizontale contagieuse des acariens.

Nothrus truncatus Banks et *Cultroribula divergens* JACOT associés aux genres *Scheloribates*, *Galumna*, *Pergalumna* et *Pseudoparasitus* se trouvaient dans les secteurs les plus humides, les plus frais, les plus riches en potassium et pauvres en sodium. *Tectocepheus velatus* (MICHAEL). *Opiella nova* (OUDEMANS) et *Zygoribatula cf. fusca* EWING furent trouvés dans les stations relativement pauvres en matière organique. A l'opposé, *Eremulus cf. cingulatus* JACOT, *Xylobates capucinus* (BERLESE) et *Rhizoglyphus sp.* furent associés aux secteurs les plus riches en matière organique.

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